# Mass vaccination, immunity and coverage:

## Modelling population protection against foot-and-mouth disease in Turkish cattle

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**Annual meeting of the Society of Veterinary Epidemiology and Preventive Medicine**
**Elsinore, Denmark, 16-18 March 2016**

## Mass vaccination

When there is an ongoing threat FMD control is often based on mass vaccination

- ≥3$PD_{50}$ vaccines typically used
  - Much lower potency than vaccines used in EU outbreaks
- Require several doses for adequate immunity
- Immunity declines with time since vaccination

**Mass vaccination**

Population immunity ≈ Population vaccination history

[No. of doses, time since last dose]

Population vaccination history ≈ Population age structure

# Mass vaccination twice a year:

## Population age-sex-vaccination distribution

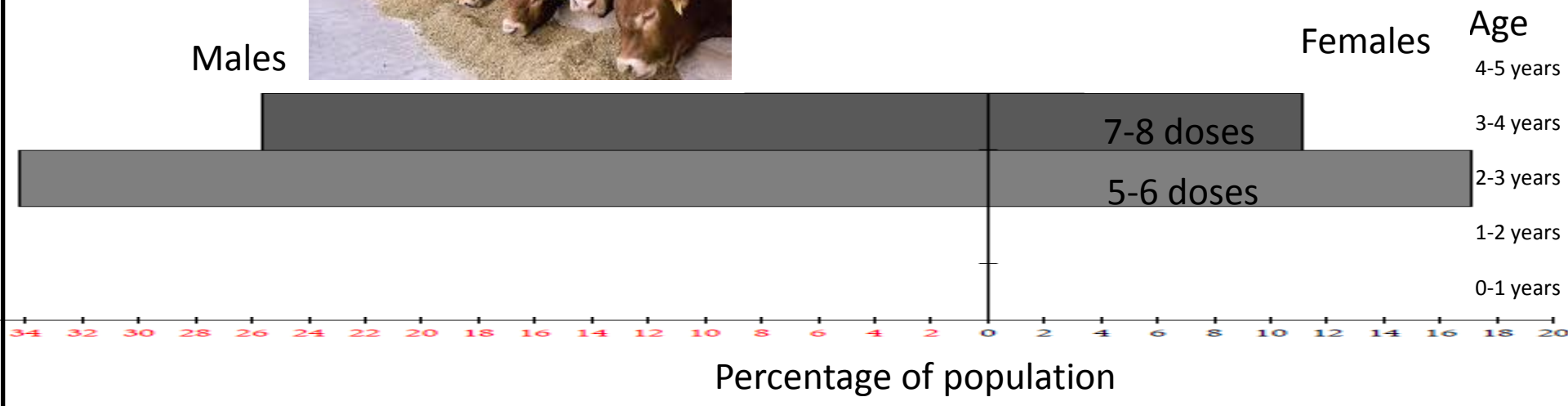
**Beef suckler cattle:**

# Mass vaccination twice a year:

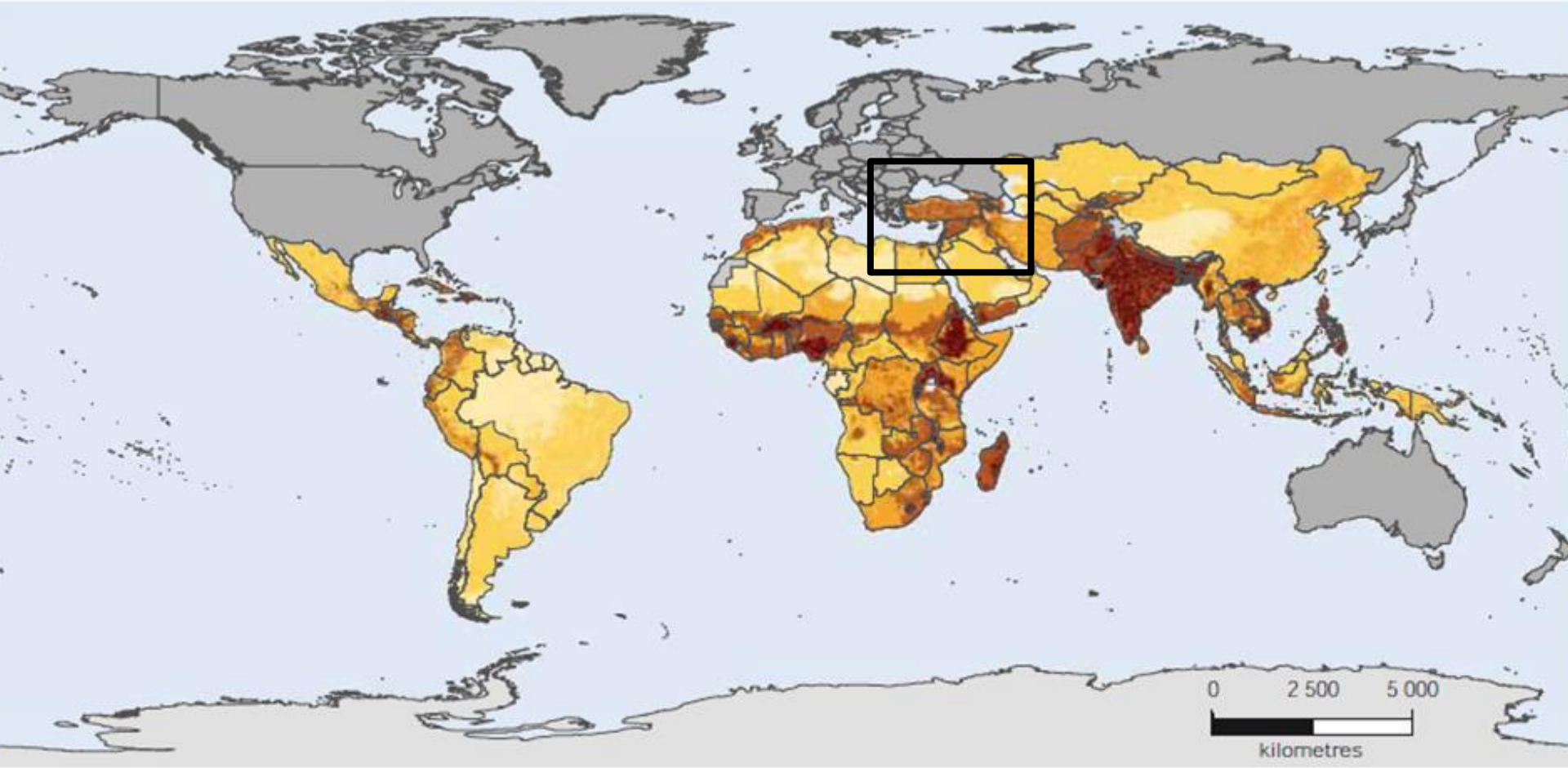
## Population age-sex-vaccination distribution

## Beef fattener cattle:

**Different production system = different age structure = different population immunity**



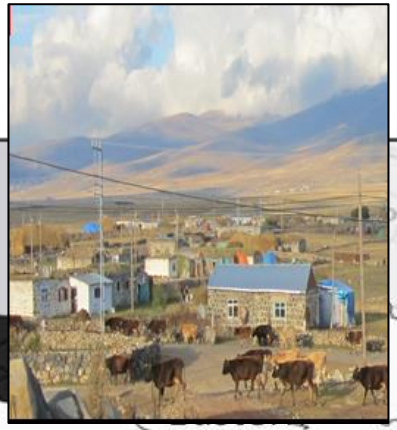
# Density of rural poor livestock keepers




*Robinson et al., 2011. Global livestock production systems. Rome, Italy: FAO and Nairobi, Kenya: ILRI*

# Population vaccine history & immunity varies by region

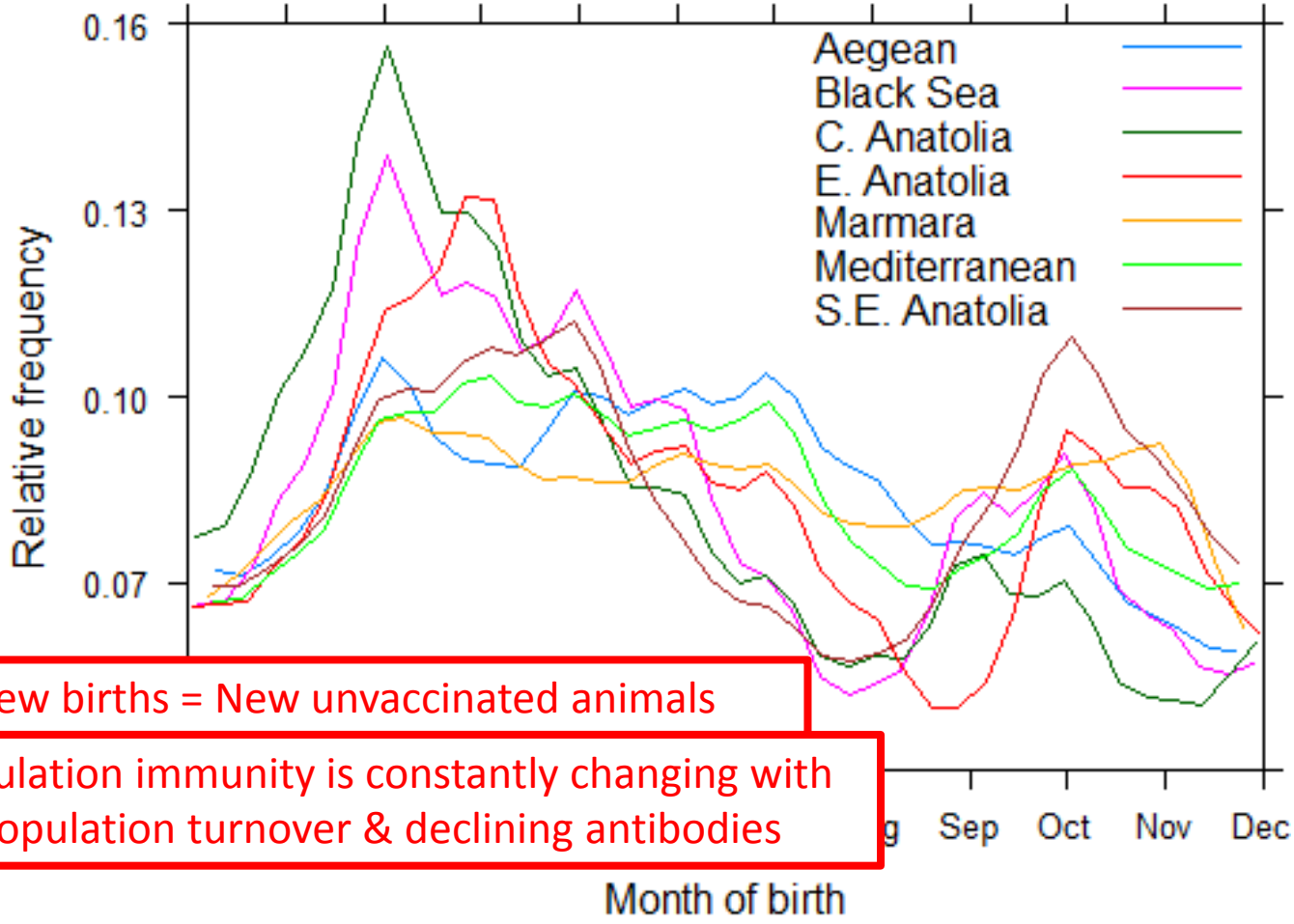
**Thrace FMD free with vaccination**
**Anatolia high FMD incidence**






**Different production system = different age structure = different population immunity**

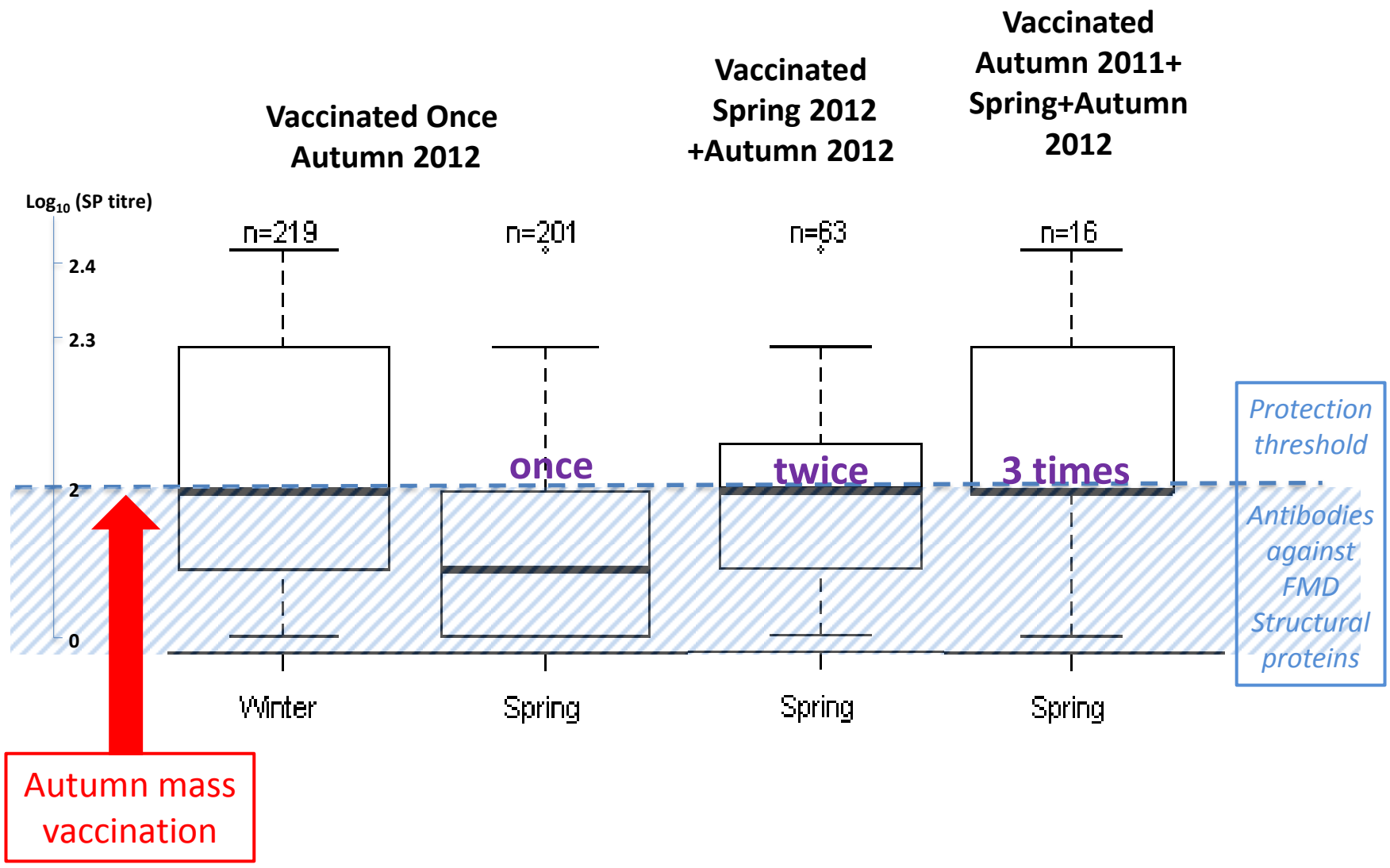
# Age-structure changes with births & deaths over the annual production cycle



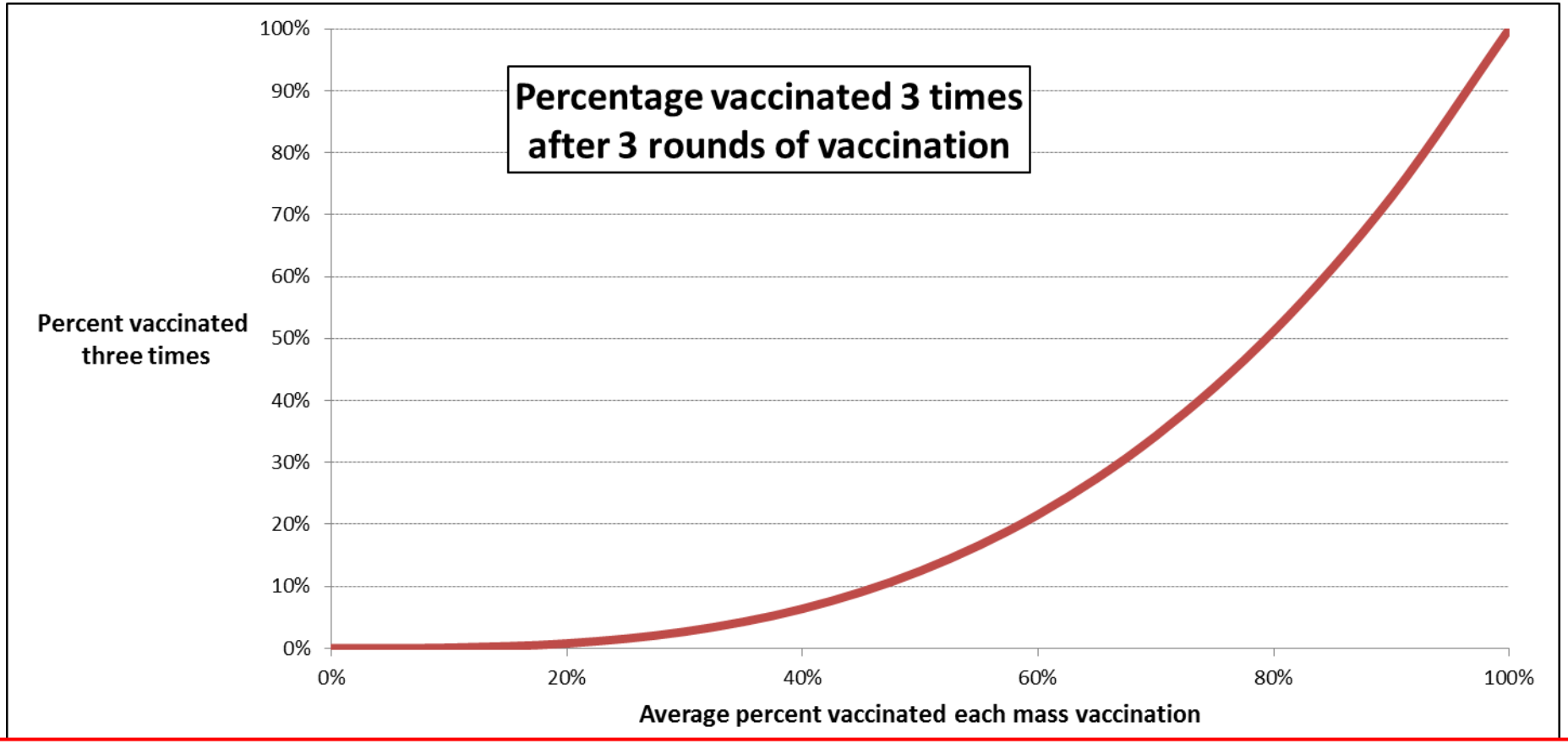

New births = New unvaccinated animals

Population immunity is constantly changing with population turnover & declining antibodies

# Post-vaccination immunity declines with time depending vaccine history



# If multiple doses needed, variation in the percentage adequately vaccinated becomes exaggerated




**With six-monthly vaccination animals will not reach 3 doses until >18 months old**

**Clustering of husbandry+age-structure+compliance+competence => Reservoirs of susceptibility**

# Population coverage model - Anatolia

- Described population vaccine immunity over the 2012 annual production cycle in Anatolian Turkey
  - Vaccinated every six months, spring/autumn (≥3$PD_{50}$ vaccine)
  - Single-dose primary course (not two-dose/prime-boost)

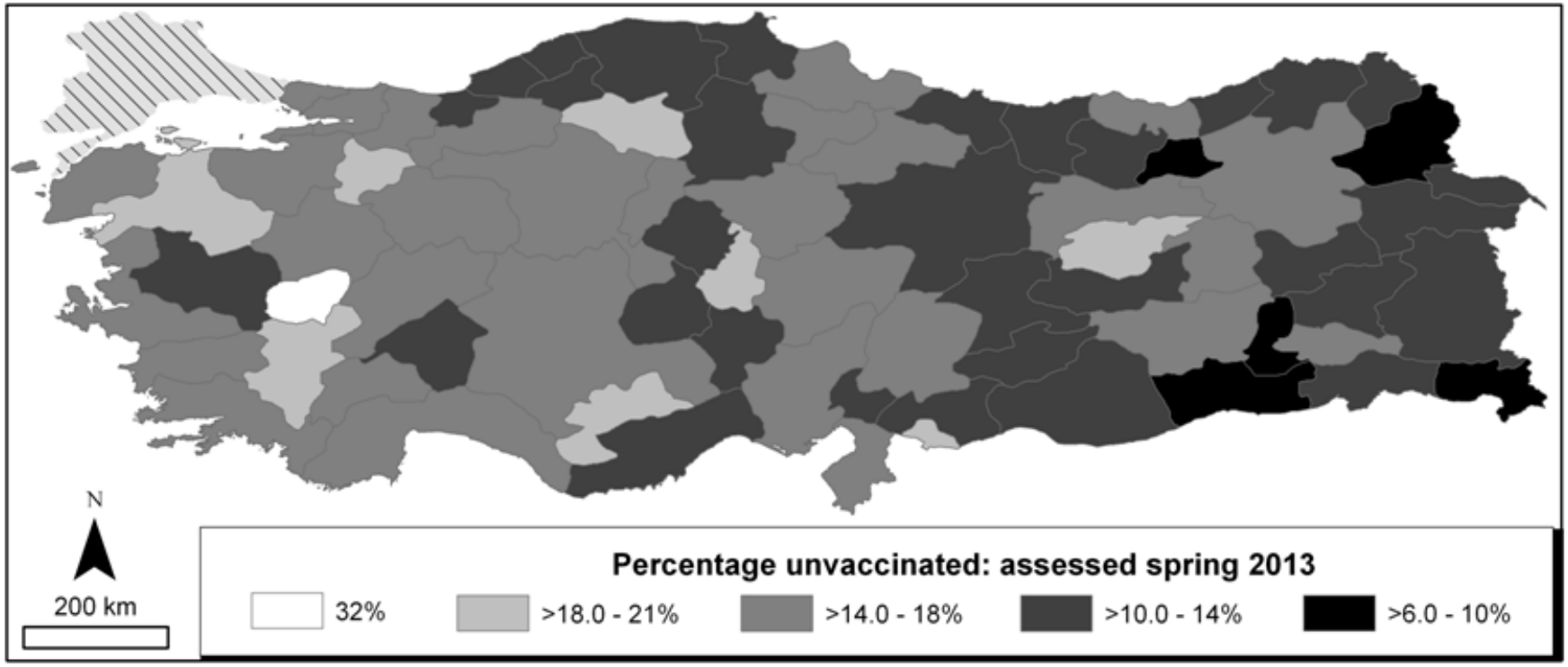
- Simulated the Turkish cattle population for each province
  - Using data from national random surveys and census data

- Dynamic population model representing the changing age structure for each province over the annual production cycle

# Percentage never vaccinated, 6 months after mass vaccination – if all eligible cattle always vaccinated

Best case scenario

*median values reported*

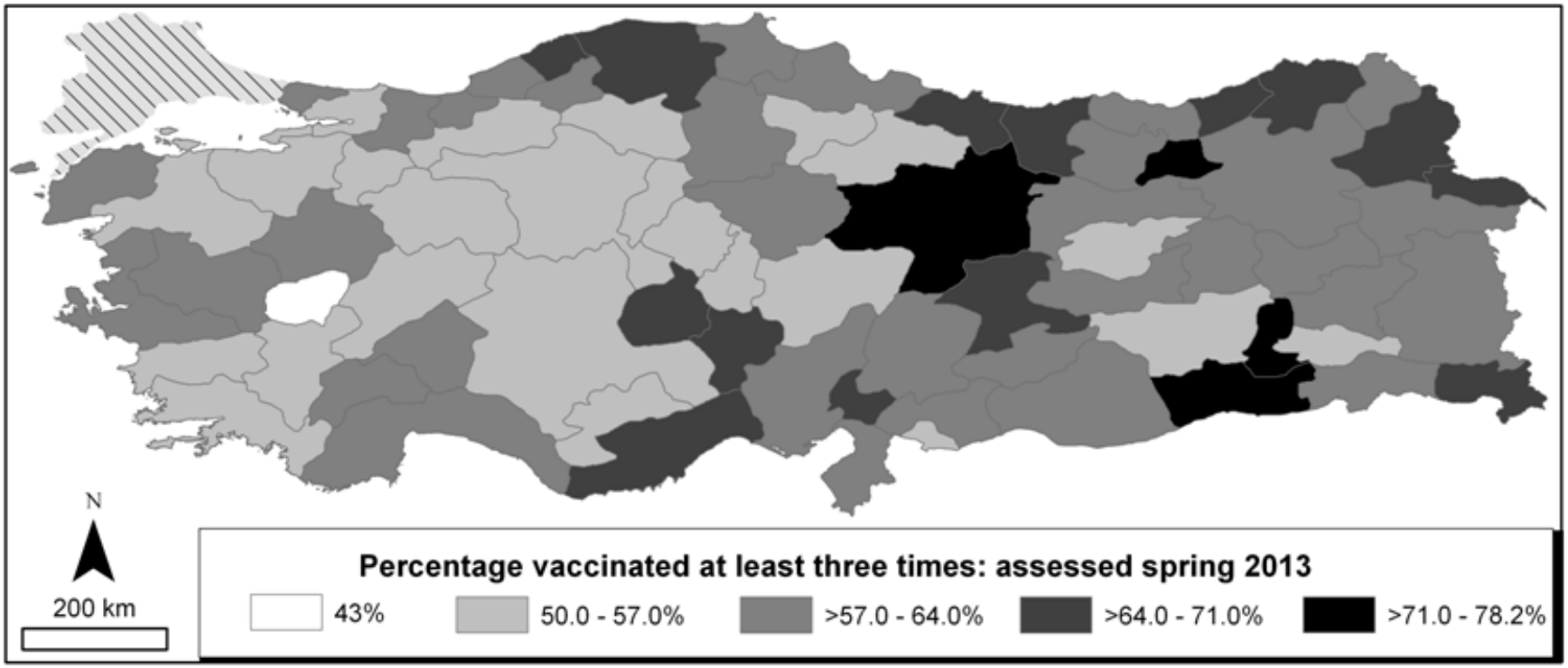



Unvaccinated = Cattle too young at prior vaccination
+
New births since prior vaccination

# Percentage vaccinated ≥3 times in lifetime – if eligible cattle always vaccinated

Best case scenario

FMD extremely infectious $R_0$ 2-70




Vaccinated ≥3 times = Adult cattle

## But not all eligible cattle will be vaccinated

Field studies and routine data found 40–100% vaccinated

Betapert distribution (minimum=40%, maximum=100%, most likely=80%)

**Results:**

- Six months after the last round of vaccination almost half of the cattle aged ≤24 months remain unvaccinated

- Only 50% of all cattle would have been vaccinated more than once with the last dose received ≤6 months ago

# From coverage to immunity

- Predict immunity for simulated population

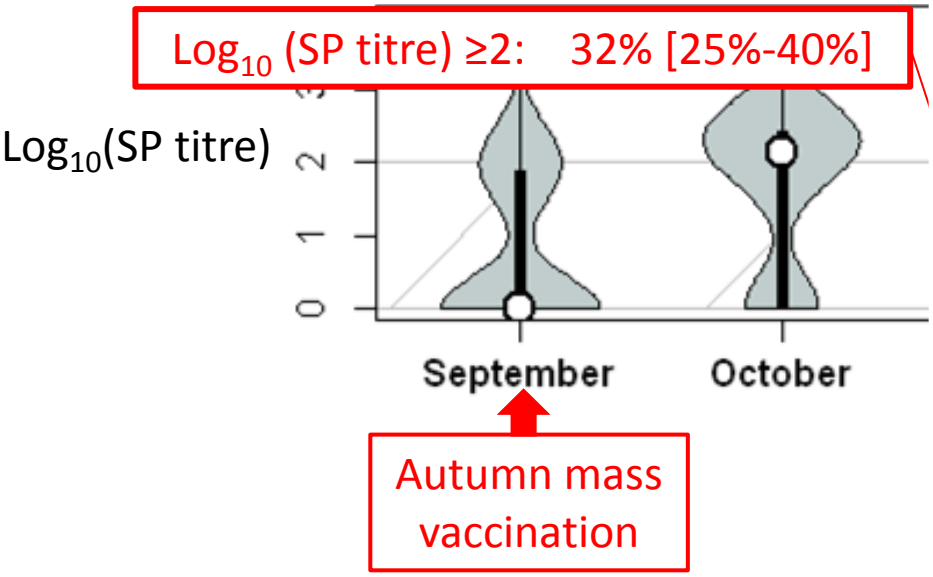
*Antibody titre = Time since vaccination + No. of times vaccinated*
*(LPBE SP)*

- Using regression models fitted to data from extensive post-vaccination sero-monitoring study [n=647]

# Population immunity predictions

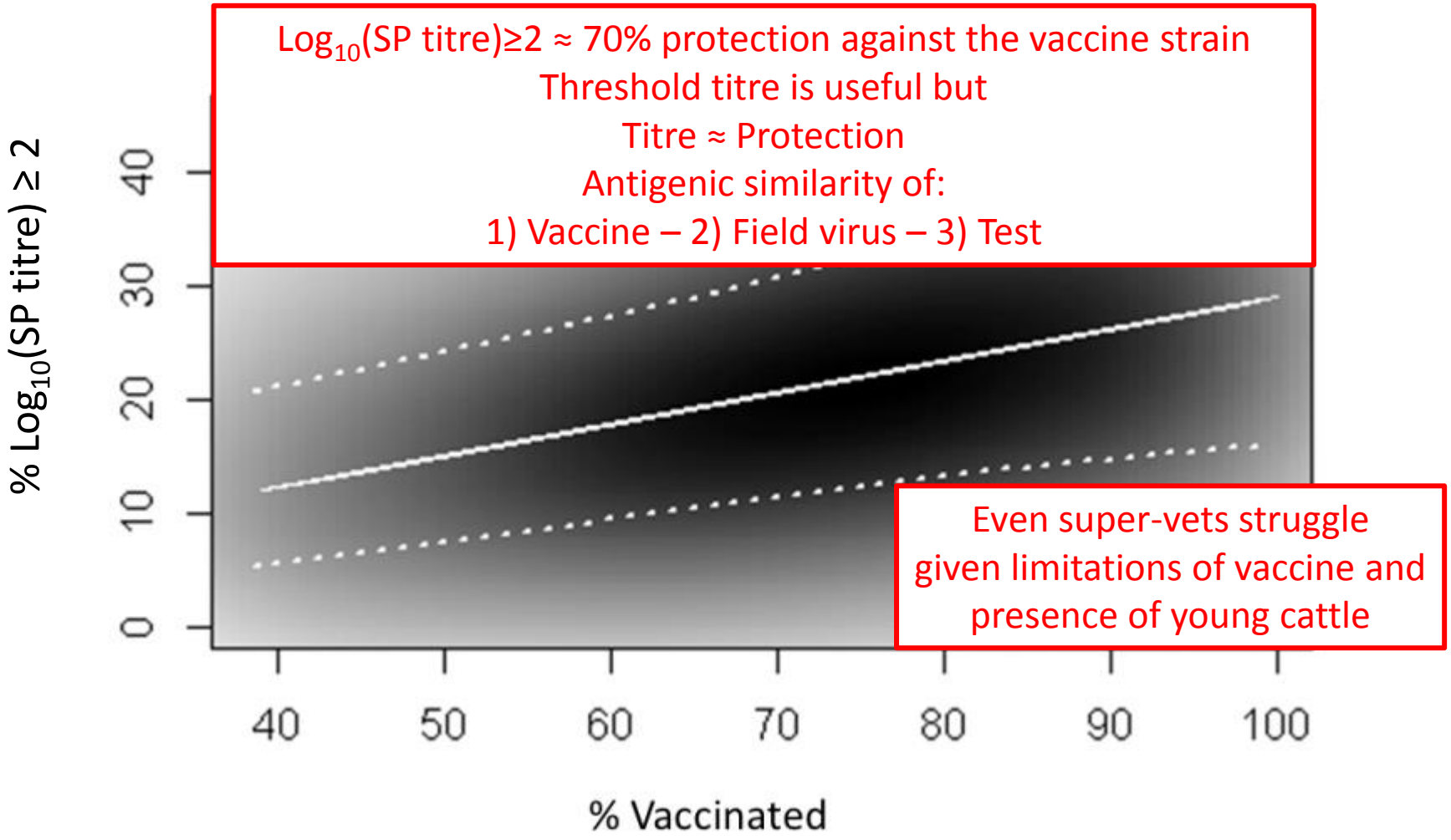
ıry course:
ırtion of
tle above
-40%

$Log_{10}$ (SP titre) ≥2: 32% [25%-40%]




Autumn mass vaccination

# District coverage and population immunity




Modelled proportion vaccinated in a district at autumn vaccination against the percentage of cattle with a serotype O SP titre ≥1:$10^2$ in mid February

# Sustained antibodies after single dose

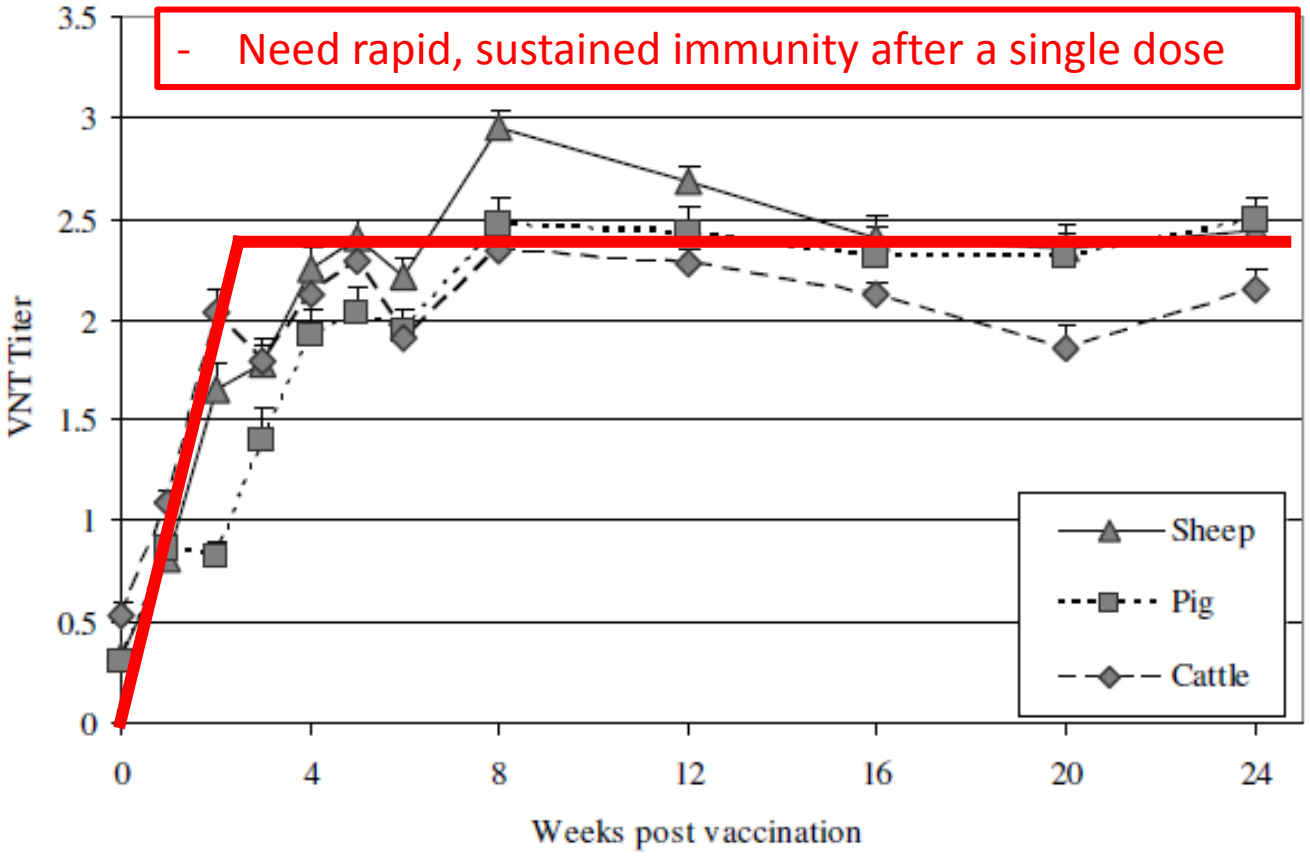



Figure 1. VNT (mean + sem) after vaccination with 6 $PD_{50}$ of O1 Manisa.

*From: Selman P, Chénard G, Dekker A (2006) Cedivac-FMD; Duration of Immunity in cattle, sheep and pigs. Open session of the EuFMD, Paphos, Cyprus, 17-19 October 2006*

# Conclusions: Mass vaccination in Turkey 2012

- Major immunity gaps despite biannual mass vaccination
- Improved vaccines required
- Prioritise repeat vaccination of young animals
  - ≥6$PD_{50}$ vaccine now routine in Turkey
  - Two-dose primary course now used
  - Accompanied by reduction in reported outbreaks

    1000 outbreaks in 2013 - 253 in 2014
- Immunity gaps will still exist
  - Each round of vaccination may exclude a quarter of all cattle
  - Vaccinated population susceptible to poorly matched strains
- Improved biosecurity measures required
  - Avoid over reliance on vaccine protection
  - Easier said than done in smallholder systems dependent on communal grazing
  - Can FMD be controlled using high potency vaccines with minimal biosecurity?

*Knight-Jones, T. J. D. et al. Sci. Rep. 6, 22121; doi: 10.1038/srep22121 (2016)*
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